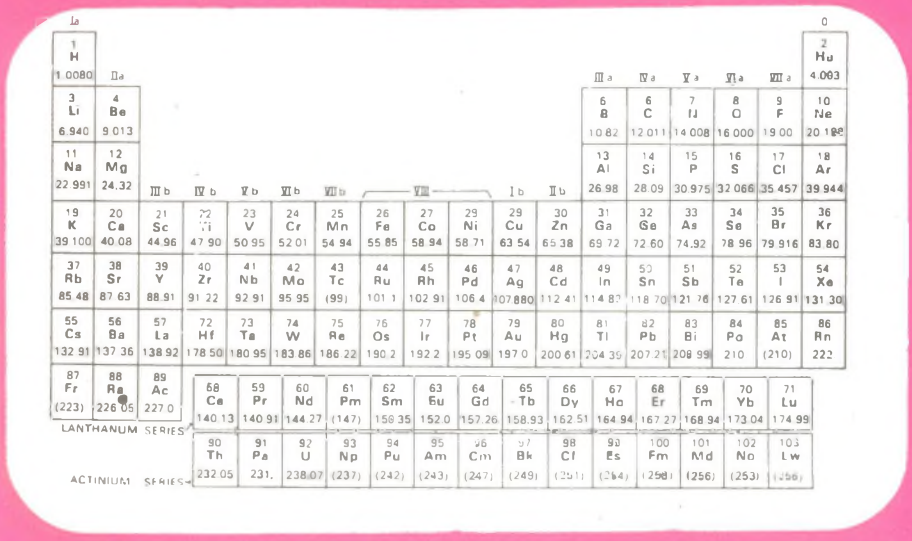
THE STORY OF THE ELEMENTS

Carbon



																	2 He 4.003
												6 B 10.82	6 C 12.011	7 N 14.008	8 O 16.000	9 F 19.00	10 Ne 20.183
												13 Al 26.98	14 Si 28.09	15 P 30.975	16 S 32.066	17 Cl 35.457	18 Ar 39.944
19 K 39.100	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.94	26 Fe 55.85	27 Co 58.94	28 Ni 58.71	29 Cu 63.54	30 Zn 65.38	31 Ga 69.72	32 Ge 72.60	33 As 74.92	34 Se 78.96	35 Br 79.916	36 Kr 83.80
37 Rb 85.48	38 Sr 87.63	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (99)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.4	47 Ag 107.880	48 Cd 112.41	49 In 114.82	50 Sn 118.70	51 Sb 121.76	52 Te 127.61	53 I 126.91	54 Xe 131.30
55 Cs 132.91	56 Ba 137.36	57 La 138.92	72 Hf 178.50	73 Ta 180.95	74 W 183.86	75 Re 186.22	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 197.0	80 Hg 200.61	81 Tl 204.39	82 Pb 207.21	83 Bi 208.99	84 Po 210	85 At (210)	86 Rn 222
87 Fr (223)	88 Ra 226.05	89 Ac 227.0															

LANTHANUM SERIES	58 Ce 140.13	59 Pr 140.91	60 Nd 144.27	61 Pm (147)	62 Sm 150.35	63 Eu 152.0	64 Gd 157.26	65 Tb 158.93	66 Dy 162.51	67 Ho 164.94	68 Er 167.27	69 Tm 168.94	70 Yb 173.04	71 Lu 174.99
ACTINIUM SERIES	90 Th 232.05	91 Pa 231.	92 U 238.07	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (249)	98 Cf (251)	99 Es (254)	100 Fm (258)	101 Md (256)	102 No (253)	103 Lw (256)

SARABHAI M CHEMICALS

THE STORY OF THE ELEMENTS

Carbon

SARABHAI M. CHEMICALS PRIVATE LIMITED
BARODA.

HISTORIC MILESTONES

1670 Diamond were first discovered in Brazil and have been mined there since 1721.

1704 SIR ISAAC NEWTON stated that the diamond must be combustible, and in 1772 LAVOISIER found this to be true.

1776 Carbon monoxide was first discovered by LASSONNE, when he heated a mixture of charcoal and Zinc oxide.

1779 SCHEELE demonstrated that graphite is oxidized to carbon dioxide, thus proving its carbon constitution.

1783–84 LAVOISIER distinguished between hydrogen and matter derived from charcaol, since they form water and carbon dioxide.

1787 GUYTON DE MORVEAU, LAVOISIER, BERTHOLLET, and FOURCROY used the term ***carbone*** for the element carbon, instead of ***charbon***.

1789 WERNER coined the word ***graphite*** from the Greek ***graphien***, " to write ".

1796 SMITHSON TENNANT proved that equal weights of carbon and diamond, when burned with saltpeter, yielded equal amounts of carbon dioxide.

1796 Carbon disulphide was discovered by W. A. LAMPADIUS, when he heated a mixture of charcoal and iron pyrites at high temperature.

1796 SMITHSON TENNANT proved that diamond consists solely of carbon.

1800 The earliest use of carbon in an electrical application is attributed to SIR HUMPHRY DAVY.

1814 SIR HUMPHRY DAVY proved, by the combustion of diamond, that it consisted only of pure carbon.

1866 Diamonds were first found in South Africa near Kimberly.

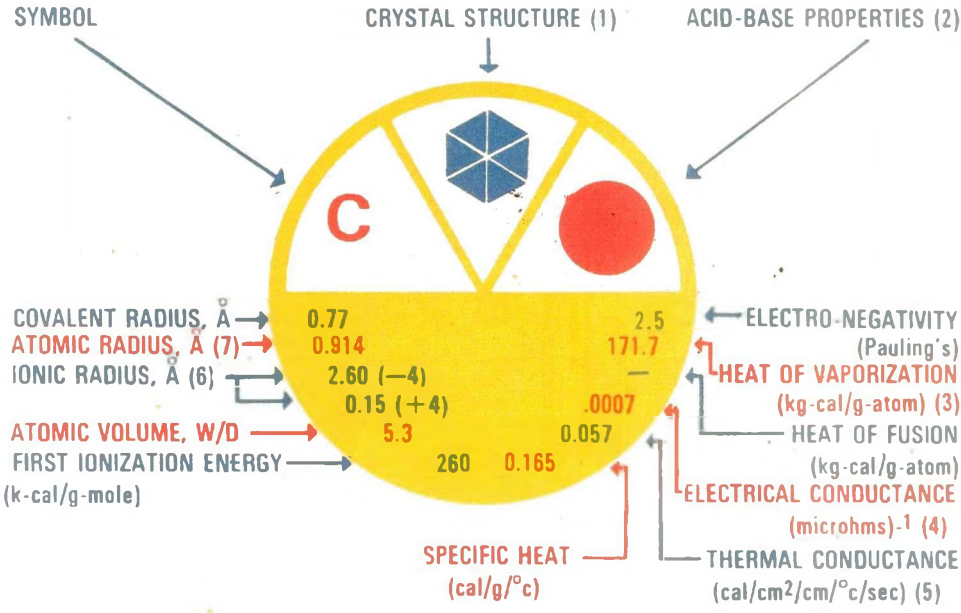
1876 The Frenchman, CARRE, is credited with making the first successful baked carbon compositions.

1893 HENRY MOISSAN claimed that he has prepared the artificial diamond.

1924 Dry ice (solid CO_2) was first used for refrigerating ice cream and food stuffs.

1955 The first successful artificial preparation of diamond was announced by the General Electric Company.

PERIODIC PROPERTIES OF CARBON



(1) Hexagonal

(2) Oxides of carbon are acidic and are indicated by red colour.

(3) At boiling point.

(4) From 0°C to 20°C.

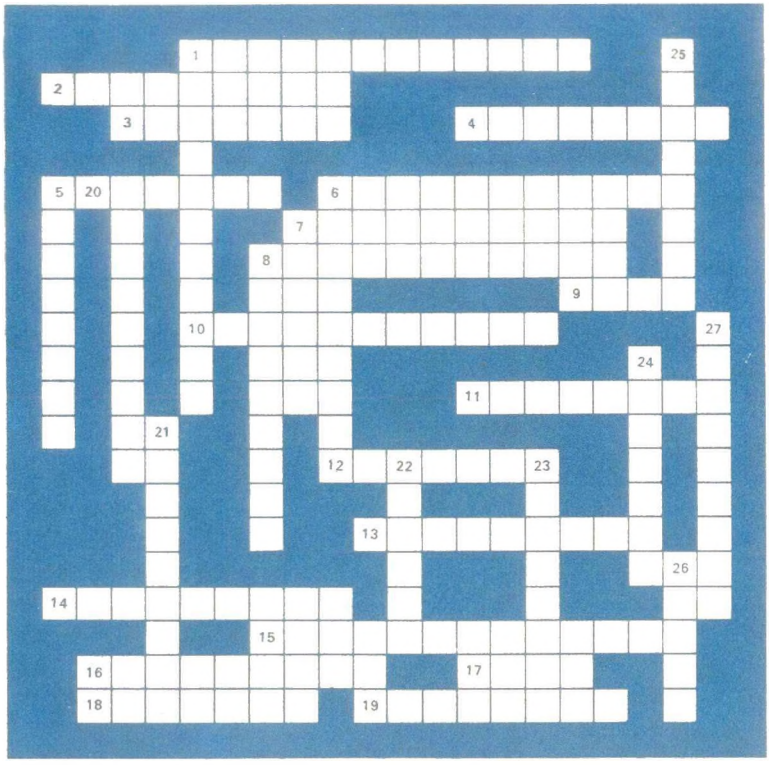
(5) At room temperature.

(6) Ionic [crystal] radii for co-ordination number 6.

(7) Metallic radii for co-ordination number of 12.

Sarabhai M. Chemicals

Chemistry Crossword Puzzle (Carbon)

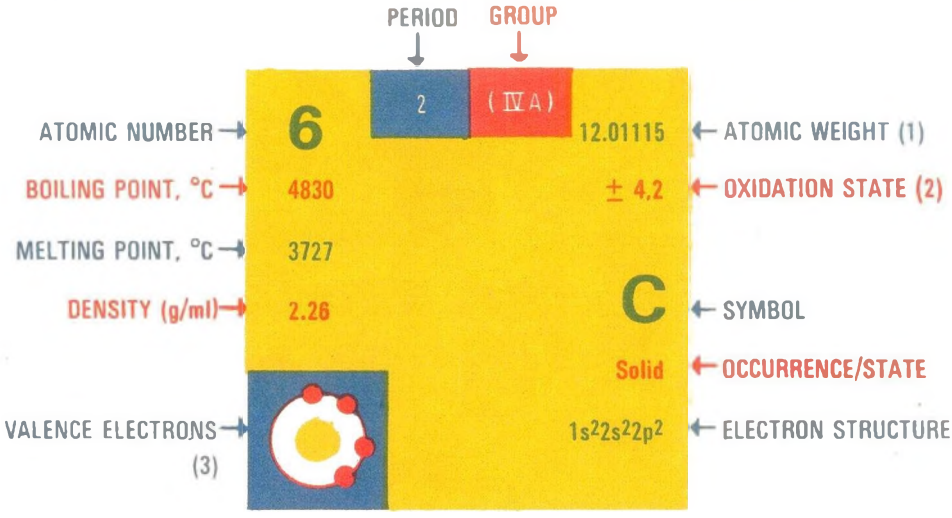


LEGEND (Clues)

HORIZONTAL

1. A large family of chemical compounds occuring in nature, which contains a long chain of Carbon.
2. A synthetic non-nutritive sweetener which is now banned due to its cardio-vascular toxicity.
3. A family of compounds formed by the inter-action of Carbon, at higher temperatures, with most of the elements of the Periodic System.
4. A gas consisting of a mixture of hydrogen and carbon monoxide.
5. The hardest, naturally occuring crystalline substance ever known.
6. One of the first "manufactured" Carbon products used in the engineering field, in particular, on electric motors and generators.
7. A class of stars with an exceptionally high abundance ratio of Carbon (C) to Hydrogen (H).
8. An amorphous form of Carbon with intense black colour, which is used as a pigment in inks, chiefly printing inks, and in automobile tyres.
9. An amorphous of Carbon, prepared by heating coal in the absence of air.
10. An important carbide compound used extensively as an abrasive.
11. A highly poisonous gas prepared by the reaction of Carbon monoxide and chlorine in the presence of sunlight.
12. A special branch of chemistry which deals with the study of a series of the numerous simple and complex compounds formed due to the combination of carbon with H, O and N etc.

PHYSICAL PROPERTIES OF CARBON



(1) Based upon Carbon-12.

(2) The element carbon has two oxidation states: ± 4 and ± 2; of which ± 4 is more stable.

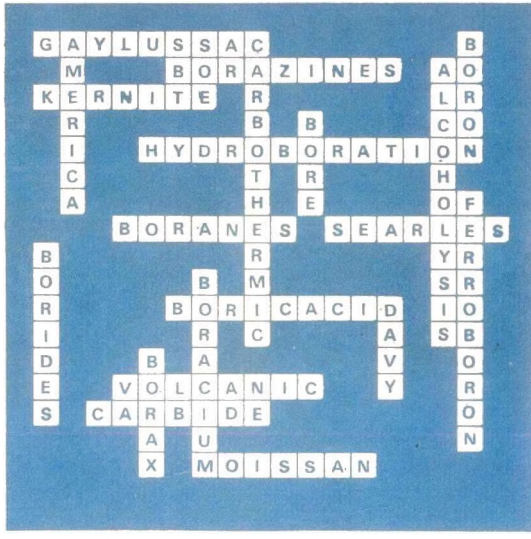
(3) Carbon has four valence electrons in its outermost orbit.

Sarabhai M. Chemicals

13. A synthetic non-nutritive sweetener used to replace sugar in order to produce a low-calorie carbonated beverage.
14. A family of "addition compounds" prepared by the combination of carbon monoxide with many metals and non-metals
15. A colourless, odourless, tasteless gas extensively used for the CARBONATION of beverages.
16. One of the two Organic species in which carbon is positively charged.
17. A combustible solid form of carbon consumed in greater tonnage than most commodities produced by man.
18. A low rank of coal between peat and sub-bitumnious coal.
19. A Tungsten metal carbide used in tools for its hardness.

VERTICAL

5. One of various minerals which contains carbon in the form of carbonate.
20. Any form of carbon characterized by high adsorptive capacity for gases, vapours, & colloidal solids. Name this form of 'Carbon'.
21. A special type of carbon electrode known after its founder, which is widely used in several electric furnace smelting operations.
1. A series of thermonuclear reactions in which hydrogen is converted to helium, with $CARBON^{12}$ acting as a catalyst. Name this reaction.
8. The other organic speci in which carbon is negatively charged.
7. The second most abundant element (oxygen being first) in the human body.
6. A dark massive form of impure diamond, sometimes known as "Black diamond"—used in the rock-drilling apparatus.
22. A greek word for graphite which means 'I write".
23. An another amorphous form of carbon, prepared by the ignition of wood.
24. An aromatic hydro carbon, of which a large number of substitution products are known.
25. One of the allotropic forms of carbon, which is very soft & crystalline in character.
26. A carbon-containing gas especially used in refrigeration devices.
27. A substance prepared from carbon & graphite which is used in the electric furnaces.



Solution to the Chemistry Cross-Word Puzzle (BORON) published in the Technical News Service Journal Vol. IV, No. 8; June-July 1972.

Since the complete story of carbon would be a history of Organic Chemistry; asphalt, carbonate rocks, alkaline carbonates, fuels, foods, plant and animal nutrition, photosynthesis and respiration; the following brief sketch can merely suggest the magnitude of the subject.

CARBON

Carbon is the nineteenth most plentiful element of the earth's crust. Because of its unique atomic structure which results in an ability to react chemically with most other elements, as well as to bond with itself, carbon is a component in hundreds of thousands of compounds — more than all other chemical combinations known. An estimated 1,000,000 carbon compounds are described in chemical literature, and chemists synthesize many new ones each year. These compounds are the subject of ***Organic Chemistry.*** Although the classification is not rigorous, carbon forms another series of compounds which are classified as ***Inorganic compounds.*** This group comprises a much smaller number than the organic compounds. Thus, carbon compounds are so numerous, complex, and important that they form a main division in the field of chemicals.

Most of the energy of our bodies, as well as that which drives our machines, is supplied by the oxidation of carbon and its compounds and every form of animal and plant life requires carbon for survival. Plants obtain it from the carbon dioxide in the air, converting carbon dioxide and water into carbohydrates in the process of ***Photosynthesis.*** Animals consume the carbohydrates, returning carbon dioxide to the atmosphere by the processes of exhalation and excretion and the decomposition of their bodies under bacterial action after death. This endless chain linking animal and plant life is known as the carbon cycle.

Occurrence

Carbon and its compounds are found widely distributed in nature. It is estimated that carbon makes up 0.032% of the earth's crust. Free carbon

is found in large deposits as coal, an amorphous form of the element which contains additional complex ***carbon — hydrogen — nitrogen*** compounds. Pure crystalline carbon is found as graphite and in small amounts as diamonds.

Extensive amounts of carbon are found in the form of its compounds. In the atmosphere, carbon is present in amounts upto 0.03% by volume as ***carbon dioxide.*** Various minerals such as lime stone, dolomite, marble, and chalk all contain carbon in the combined form as ***carbonate.*** All plant and animal life is composed of complex organic compounds containing carbon combined with hydrogen, oxygen, nitrogen, and several other elements.

The remains of past plant and animal life are found as deposits of petroleum, asphalt and bitumen. Vast deposits of natural gas contain compounds composed of carbon and hydrogen.

Some of the important ***forms*** of carbon, such as coal, diamond, graphite, lignite, etc occur in the mines located in the different parts of India.

The most important ***coal*** fields are Raniganj in West Bengal, and Jharia and Bokaro in Bihar. The best coking coal comes from Giridith Jharia and Raniganj. Other states in which coal is found are Madhya Pradesh, Orissa, Andhra Pradesh, Tamilnadu, Maharashtra, Assam, Rajasthan and Kashmir. The principal producers of coal in the world are the United States of America and Germany, followed by Great Britain and U. S. S. R.. These four countries together account for more than 70% of the world's output.

Lignite is the name applied to unconsolidated coal. It is distinguished from coal by its brown colour, and amorphous, fibrous and woody texture. Lignites are widely distributed in all the continents, except possibly Antarctica. The occurrences in North America; and Europe are extensive. In India, lignite occurs at Palana and Khari in Bikaner district, Rajasthan; Nicholam in Jammu and Kashmir; Kutch and Broach in Gujarat. Besides this, lignite also occurs in Kerala, Tamilnadu, and in Siwaliks and Pleistocene of the Himalayan regions.

Graphite occurs in crystalline masses, or as tubular or scaly crystals in the States of Rajasthan, West Bengal, Bihar, Andhra Pradesh, Jammu and Kashmir, Madhya Pradesh, Tamilnadu, Mysore, Orissa, Punjab, Kerala and Uttar Pradesh.

Diamonds were first discovered in most countries in secondary deposits, i. e. in sands and gravels of stream deposits — river diggings. The most important deposits of diamonds are located in Belgian Congo, Gold Coast, Sierra Leone, Angola, Union of South Africa and South-West Africa. Other

notable areas are in Brazil, British Guiana and Borneo. The diamond mines of South Africa supply most of the world's requirements. In India, diamonds are found from the states of Andhra Pradesh and Madhya Pradesh — the latter being the only region in the country where the diamond mining industry is extant.

Carbon — as a Free Element

Carbon is of prehistoric discovery, and exists in three forms : ***diamond***, ***graphite*** and ***amorphous carbon.*** All these forms of carbon occur naturally as well as prepared through synthetic routes too.

The principal valency of carbon is ***four***, but a few compounds of ***mono-***,***di-***. and ***tri***-valent carbon have been prepared. The four valency electrons of the carbon atom may be shared with those of other atoms to form a stable system of electrons (***an electron octet***).

The symbol of carbon is C ; atomic number 6; atomic weight, 12.01115; atomic radius, 0.914 ***Angstrom*** (single bond); and orbital arrangement of electrons, $1s^2\ 2s^2\ 2p^2$, where the superscript indicates the number of electrons in the corresponding sublevel. Carbon sublimes at >3500°C, and boils at about 4880°C. Six isotopes of carbon are known : C^{10}, C^{11}, C^{12}, C^{13}, C^{14} and C^{15}. Isotopes 12 and 13 are stable; the others are radioactive, having half-lives as follows : C^{10},20 Sec; C^{11}, 20.5 min; C^{14}, about 5360 yr; C^{15}, 2.4 Sec.

Elemental carbon is a fairly inert substance. It is insoluble in water, dilute acids and bases, and organic solvents. At elevated temperatures it combines with oxygen to form carbon monoxide, or carbon dioxide. With hot oxidizing agents such as nitric acid and potassium nitrate, mellitic acid, $C_6(COOH)_6$ is obtained. Of the halogens, only fluorine reacts with the elemental carbon. This carbon – fluorine union, at room temperature, yields tetrafluoride (CF_4). A number of metals combine with the element at elevated temperatures to form carbides. At ordinary temperatures, it combines with sulphur vapour to form carbon disulphide (CS_2). It combines directly with hydrogen to form acetylene (C_2H_2) when an electric arc is passed between carbon poles surrouned by hydrogen; small portions of methane (CH_4) and ethane (C_2H_6) are also produced. At a lower temperature (1200°C), almost quantitative yields of methane are obtained. At higher temperatures carbon is a good reducing agent and large quantities of it, in the form of coke, are used in metallurgical processes for the reduction of metallic oxides such as those of iron and zinc.

The free element has many uses, ranging from ornamental applications of the ***diamond*** in jewellary to the black–coloured pigment of carbon black in automobile tires and printing inks. Another form of carbon, ***graphite*** is used for high temperature crucibles, arc–light and dry–cell electrodes, lead pencils, and as a lubricant. ***Charcoal***, an amorphous form of carbon, is used as an adsorbent for gases and as a decolourizing agent.

The compounds of carbon find many uses. Carbon dioxide is used for the carbonation of beverages, for fire extinguishers, and in the solid state, as a refrigerant. Another oxide of carbon, carbon monoxide, finds use as a reducing agent for many metallurgical processes. Carbon tetrachloride and carbon disulphide are important solvents for industrial uses. Gaseous dichlorodifluoromethane, commonly known as ***freon***, is used in refrigeration devices. Calcium carbide is used to prepare acetylene, which is used for the welding and cutting of metals, as well as for the preparation of other organic compounds. Other metal carbides find important uses as refractories and metal – cutting tools.

Allotropy of Carbon

Carbon occurs in two allotropic crystalline forms, viz, ***Graphite*** (hexagonal system) and ***Diamond*** (isomeric system); the former is soft and black, while diamond is hard and transparent. Charcoal, coke, and carbon black, classified as ***Amorphous carbon***, are considered to represent a third allotropic form.

Graphite

Graphite is a mineral consisting essentially of carbon but often impure with clay, iron oxide, or other minerals. Graphite is one of the softest minerals with hardness 1–2 on the Mohs scale. It soils the fingers when handled, leaves a black mark on the paper, and has a greasy feel. Graphite commonly occurs in foliated mass but may occur as radiated, granular, earthy, or columnar aggregates.

Graphite crystailizes in the hexagonal system. Crystals are rare and six–sided tablets with 60° triangular markings on the broad faces. Physically, graphite strongly resembles ***molybdenite*** (molybdenum sulphide) with which it has been confused for centuries. Molybdenite also crystallizes in the hexagonal system, is platy, and soft enough to live a mark on paper. The mark left by molybdenite on glazed paper is greenish, whereas the mark left by graphite is black. Graphite has also been confused with lead sulphide, galena; hence the trade names ***plumbago*** and ***black lead*** both refer to graphite.

The colour of graphite is black to steel–gray, and the thinnest flakes are a deep blue in strong transmitted light. There is one perfect cleavage allowing the mineral to be split into thin, flexible, but non–elastic folia. It apears to be the most stable form of carbon as indicated by its heat of combustion. Most varities of graphite are attacked by strong oxidizing agents such as mixtures of sulphuric acid with nitric acid, chromic acid or chlorates to give graphitic acids and finally mellitic acid, $C_6(COOH)_6$ — diamond remains unaffected by such treatment. Graphite conducts electricity, a property which permits it to be distinguished from amorphous carbon.

Since natural graphite is indispensable for certain purposes, and is insufficient to satisfy the ever increasing demands of the industry, a synthetic route has been worked out to manufacture graphite.

Synthetic graphite can be made from almost any organic material that leaves a high carbon residue on heating to 2500–3200°C.

Graphite has many uses in the electrical, chemical, metallurgical, nuclear, and rocket fields : electrodes in electric furnaces producing corbon steel, alloy steel, and ferro alloys; anodes for electrolytic production of chlorine, caustic and chlorates, magnesium and sodium; motor and generator brushes; sleeve-type bearings; seal rings; electronic tube anodes and grids; nuclear reactor mode-rators, reflectors, and thermal columns; rocket motor nozzles; missile rudder vanes; metallurgical moulds and crucibles, linings for chemical reaction vessels; and in the resin–impregnated impervious form, for heat exchangers, pumps, piping, valves, and other process equipment.

Diamond

Diamond, the ***high-pressure modification*** of carbon, when heated above 1300°C, changes to graphite, the ***high-temperature modification*** of carbon. Diamond is stable and chemically inert at moderate temperatures. Though diamond is the hardest known substance, it is quite friable and is readily crushed to grit and powder, the form in which approximately 75% of all diamond is used.

Diamond as a natural mineral, ranges widely in purity, soundness, size, colour, and shape. It is thus necessary to sort diamonds as mined into the many catagories according to potential uses. Those of near flawless quality having colours of blue, blue–white, water–white, pink, or a slight tinge of yellow are of greatest value as gems. Approximately 20% of diamonds mined are classified as gems. Other sound stones, but poor in colour and clarity, are used in tools and dies. Diamond unsuitable for use as gem or tool stones are crushed to grit and powder.

The high index of refraction (2.42) and the high optical dispersion give the gem diamond its brilliance. Diamond is the most valued of all gems because of these properties and its durability, and because of its scarcity. The diamond, in nature, occurs in a wide range of shapes, sizes, and crystal perfection. They occur as near perfect single crystals, twins, dense agglomerates of crystallites, and crystals with foreign inclusions and ingrowths. Many of these shapes and forms have been found particularly useful in industrial applications.

Diamond is the hardest of ail materials, yet it is readily fractured by impact. Diamond has a value of 10 (the highest) on the Mohs scale. It will scratch or abrade all materials, including diamond. Diamond may be colourless, blue, green, yellow, pink, brown, or black. The intensity of these colours varies greatly. Pure diamonds are colourless and transparent, but their colours are due to small amounts of impurities. All except the yellow stones are highly valuable as gems. ***Carbonado*** and ***Bart*** are black diamonds; they are valueless as gems, but on account of their extreme hardness they are extensively used In making tools, for drilling, cutting and grinding.

Spectrographic analysis of diamonds of various types shows silicon, magnesium, aluminium, calcium, iron, and copper as the more abundant impurities, appearing in quantities upto 79 ***ppm.*** Diamond burns in the air about 800°C. In helium atmosphare, graphitization does not occur below 1200°C; it occurs superficially at 1300°C, and proceed at a rapid rate at 1500°C and above. Diamond powder apears to graphitize at a slightly lower temperature than clear single crystals or macles. Diamond is chemically inert at moderate temperatures but readily reacts with molten carbonates, nitrites, and carbide-forming metals.

Many attempts have been made to manufacture diamonds prior to the announcement (Feb. 15, 1955) by the General Electric Company of their successful synthesis. All claims of success prior to 1955 have been proven erroneous. Synthetic diamonds are identical with natural diamonds are indentical with natural diamonds in fundamental properties but differ in those characters that depend on the process of manufacture, such as impurities, size, and shape.

Diamond in its various forms is in ever increasing demand. As single stones, diamonds are used as tools to dress conventional grinding wheels. Diamond stones are used in turning operations, because of the fine surface finish, it can generate on materials such as brass, bronze, silver, gold, aluminum, plastics, and fiber. Diamond wire dies, phonograph needless, indenters, glass cutters, and ruling tools for ruling of diffraction gratings are shaped

from diamond crystals. Microtome knives, having the keenest edge ever made, are lapped from diamond. The largest volume of dimond is used in the form of grit and powder, to prepare diamond–impregnated tools such as grinding wheels, saws, drills, etc. Ophthalmic and technical lenses are generated and finished with diamond–impregnated tools. As new materials are developed for solid–state electronics, space vehicles, and jet planes, new techniques are needed for shaping them. Diamond tools are frequently the only answer. Although the unit cost of diamond tools may be considered high, economic advantage is obtained through labour cost, high efficiency, and the fact that many materials can be shaped only with diamond.

Amorphous Carbon

This heading covers ***coke***, ***lampblack***, ***carbon black*** or ***gas black***, ***gas carbon*** or ***retort carbon***, ***soot*** and ***charcoals***, of which there are many varieties, each depending upon the process employed in the manufacture and upon the starting material.

Actually, X–ray examination of various ***amorphous carbons*** has shown them to be more or less crystalline, resembling graphite in structure; but there are many intermediate stages between amorphous carbon and graphite. All varieties are more or less readily attacked by the strong oxidizing agents that react with graphite.

Carbon black is used extensively in the manufacture of automobile tyres, printer's ink, dry cells, and antistatic phonograph records. It is also used as a grinding agent in the cement industries, and as a colouring pigment in linoleum, leather coatings, polishes, plastic tile, and concrete. Carbon brushes and electrodes are also fabricated from carbon black. It is an excellent fuel and adsorbent in liquid oxygen explosives.

The ***charcoals*** (sugar charcoal, wood charcoal, animal charcoal, or bone black, etc) are very porous, and consequently their specific gravity is apparently only about 0.25, but when air is pumped out of the pores, this becomes 1.4 – 1.9. Charcoal is hard and brittle and is a poor conductor of electricity. Like soot it is dead black and without lustre. Charcoal is prepared by the ignition of wood, sugar, blood, and other carbon–containing compound in the absence of air.

Coke, another form of amorphous carbon, is prepared by heating coal in the absence of air. It is used primarily for the reduction of metal oxides to the free metals.

One of the most important varieties of black carbon is ***activated carbon.*** This product is made by heating inactive carbon in steam (or other gases). It has a great capacity for adsorbing dissolved substances, as well as great capacity for adsorbing gases. This properly makes activated carbon valuable as a decolourizing agent, as, for example, in sugar refining, and also useful for the removal of many gases and vapours from contaminated air. It is the principal component in gas masks.

Compounds

Carbon dioxide

Carbon dioxide, CO_2, exists in three forms : ***solid***, ***liquid*** and ***gas.*** In ***solid state,*** it exists as white, snow-like flakes or cubes best known as ***dry ice.*** ***Liquid form*** is colourless, odourless and volatile. So also ***gaseous form*** – colourless and odourless. All forms are non-combustible and soluble in water, hydrocarbons and most organic liquids.

Carbon dioxide can be prepared in all the three forms through various routes.

(a) ***Gaseous CO_2*** — CO_2 is present in air to extent of 0.03% by volume, and 0.0474% by weight, but is not economically recoverable. Its chief sources are as follows : (1) end product of combustion and respiration, (2) cracking of hydrocarbons, (3) fermentation of carbohydrates, (4) action of heat or acid on limestone, marble, and other carbonates, (5) natural springs or wells.

(b) ***Liquid CO_2*** — can be derived by compressing and cooling the CO_2 gas to about – 37°C.

(c) ***Solid CO_2*** — Dry ice can be prepared by expanding the liquid to vapour and snow in presses that compact the product into blocks. The vapour is recycled.

Applications of carbon dioxide cover many fields, a few are given below :

Refrigeration; carbonated beverages; chemical intermediate (carbonate, synthetic fibers, ***para***xylene, etc); low temperature testing; fire extinguishers; inert atmosphere; aerosols; municipal water treatment; medicine; enrichment of air in green-houses; fracturing and acidizing of oil wells; mining (Cardox method); miscellaneous pressure source; hardening of foundry molds and cores: shielding gas for welding; cloud seeding; moderater in some types of nuclear reactors; immobilization for humane animal killing; special lasers; as a small – scale source of power ; fog – seeding to improve visibility at airports.

Carbon monoxide

Carbon monoxide, CO, is a colourless and odourless gas or liquid, burning with a violet flame. It is soluble in alcohol and benzene, and slightly soluble in water. It is highly toxic by inhalation, and also a major air–pollutant.

Carbon monoxide is obtained in pure form by various methods. It is derived almost pure (a) by placing a mixture of oxygen and carbon dioxide in contact with incandescent graphite, coke or anthracite, (b) by the action of steam on hot coke or coal (water gas) or on natural gas (synthesis gas). In the latter case, carbon dioxide is removed by absorption in amine solutions, and the hydrogen and carbon monoxide separated in a low–temperature unit, (c) as a by–product in chemical reactions, (d) by combustion of organic compounds with limited amount of oxygen as in automobile cylinders, (e) by dehydration of formic acid.

Relatively pure carbon monoxide, upto concentrations has been used in the manufacture of acids, esters, and hydroxyacids such as acetic and propionic acids, methyl acetate, ethyl propionate, methyl formate, and hydroxyacetic acid. From these chemicals numerous other derivatives are manufactured such as higher esters, ketones, aldehydes, glycols, and plasticizers. It is also used in a mixture with ethylene to preserve the life of perishable foods. A gas containing less than 0.5%, O_2, 1.5–6% CO, and C_2H_2 will inhibit the growth of organisms and inhibit the action of enzymes. Carbon monoxide has also been tried as a deoxidant in the manufacture of steel. It finds use in the manufacture of catalysts.

Carbon disulphide

Carbon disulphide, CS_2, is a clear, colourless to yellow, highly inflammable liquid with strong disagreeable odour. It is soluble in alcohol, benzene, and ether; slightly soluble in water.

It is prepared (a) by the reaction of natural gas or petroleum fractions with sulphur; (b) from natural gas and hydrogen sulphide at extremely high temperature (plasma process); (c) by heating sulphur and charcoal and condensing the carbon disulphide vapours.

Its field of application includes viscose rayon; cellophane; manufacture of carbon tetrachloride and floatation agents; veterinary medicine; and solvent.

Carbon Tetrachloride

Carbon tetrachloride, or tetrachloro methane, CCl_4, is a colorless liquid possessing sweetish, distinctive odour. It is miscible with alcohol, either

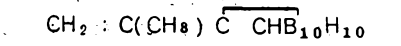
chloroform, benzene, solvent naphtha, and most of the fixed and volatile oils. It remains insoluble in water. It is non-combustible.

Carbon teterachloride is derived (a) by the interaction of carbon disulphide and chlorine in presence of a (iron); (b) by chlorination of methane or higher hydrocarbons at 250 – 400°C. The crude product is then purified by the treatment of alkali followed by rectification.

The most important single use of carbon tetrachloride is as a starting material in the production of chlorofluoromethane refrigerants and propellants. Its nonflammability, low boiling points, and high density of its vapour make carbon-tetrachloride a very effective fire extinguisher. The toxic character of carbon teterachloride is the basis of its use as a grain fumigant, either alone or in admixture with 2 – 25 % of ethylene bromide, or dichloride. Flour may be bleached and matured by exposure to carbon tetrachloride at a rate of 350 g/196 lb flour (i. e. per barrel) for 15 hours; the bleaching may also be effected by a solution of benzoyl peroxide in carbon tetrachloride. The use of carbon tetrachloride in the treament of wet wheat to inhibit spoilage has not been found to affect the baking quality of the resulting flour. Pharmaceutically, CCl_4 is used in the treatment of hookworm and liver fluke in cattle and sheep. In the petroleam refining, CCl_4 can be used to separate *p*–xylene from other eight carbon hydrocarbons. Some recently proposed applications of carbon tetrachloride are in the separation of coal from shale, as a machining lubricant, and in the synthesis of nylon–7.

Carborane

Carborane is a compound constaining carbon, boron, and hydrogen as its constituents. It is best prepared by the reaction of pentaborane or decaborane, acetylene, and hydrogen at 220°C for 48 hours. The first member of the class is 1–*iso*–propenylcarborane,



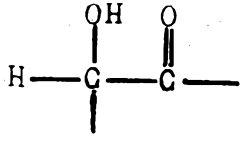
Carborane polyesters are used as ablative materials. A continuous process using temperatures of about 500°C and an excess of acetylene has greatly increased efficiences of production. Research on these compounds continues in view of their possible use as rocket fuels. Other potential uses are in synthesis of polymers, lubricants, and pharmaceuticals.

Carboxylic Acids

Any of a broad array of organic acids comprised chiefly of alkyl (hydrocarbon) groups (CH_2, CH_3), usually in a straight chain (aliphatic), terminating in a carboxyl radical (-COOH). An exception is the simplest member, formic acid (HCOOH). The number of carbon atom ranges form 1 (formic) to 26 (cerotic), the carbon of the terminal group being counted as part of the chain. Carboxylic acids, include the large and important class of fatty acids, and may be either saturated. A few contain halogen atoms (chloroacetic). There are also some natural aromatic carboxylic acids (benzoic, salicylic) as well as alicyclic type (abietic, chaulmoogric). A group of organic acids, containing both a basic amino group (NH_2) and an acidic carboxyl group (COOH), also exists and is known as 'amino acids'. Amino acids are amphoteric and exist in aqueous solution as dipolar ions. Two types of amino acids exist : essential and non-essential. An essential amino acid is one which cannot be synthesized by the body and is necessary for survival, namely, isoleucine, phenylalanine, leucine, lysine, methionine, threonine, tryptophan, and valine. Non-essential amino acids (alanine, glycine, and about a dozen others) can be synthesized by the body in adequate quantities.

Carbohydrates

Carbohydrate is a compound of carbon, hydrogen, and oxygen that contains the saccharose grouping



or its first reaction product, and in which the ratio of hydrogen to oxygen is the same as in water.

Carbohydrates are the most abundant class of organic compounds, constituting three-fourths of the dry weight of all vegetation. They are also widely distributed in animals and lower forms of life. They comprise : (1) ***monosaccharides*** : simple sugars, such as fructose (levulose) and its isomer glucose (dextrose), both having the formula $C_6H_{12}O_6$; (2) ***disaccharides*** : sucrose ($C_{12}H_{22}O_{11}$), maltose, cellobiose, and lactose; and (3) ***polysaccharides*** (high polymeric substances). The last group includes the entire starch and cellulose families, as well as pectin, the seaweed products agar and carrageenan, and natural gums.

The simple sugars are crystalline and water-soluble, with a sweet taste ; starches are water-soluble, tasteless and amorphous; cellulose is insoluble in water and other organic solvents, and is only partially crystalline. Galactose, sorbose, xylose, arabinose and mannose are constituents of more complex sugars. The natural gums are water-soluble plant products composed of monosaccharide units joined by glycosidic bonds (Gum arabic, Gum tragacanth).

Carbon Cycle

In biology, the carbon cycle is a series of chemical reactions in which carbon is removed from the air, used by living organisms, and returned to the air. Although carbon is the most characteristic element in all organic compounds and essential to life, most of the world's carbon is in carbon dioxide (CO_2) in the atmosphere. Green plants in the light are almost unique in taking the carbon from CO_2 and building it into organic compounds. Release of the carbon from these compounds (usually in the form of CO_2) is accomplished by green plants in darkness, by nongreen plants and animals at all times, and by fire as well as industrial processes. All living organisms participate in this cycle of carbon and maintain in their organic compounds the same minute proportion of radioactive carbon^{14} as occurs naturally in atmospheric CO_2. At death, however, participation in the cycle stops, and the proportion of radioactive carbon in the organism slowly decreases at a definite rate over a period of thousand of years. Measurment of this change is the basis of so-called ***Carbon dating.***

In physics, the carbon cycle is a series of thermonuclear reactions in which hydrogen is converted to helium, with carbon^{12} acting as a catalyst. First, investigated by HANS BETHE (1939) and held to account for energy production in the Sun and other stars, the cycle is assumed to take place in this series of steps :

(1) A carbon^{12} nucleus fuses with a proton (hydrogen nucleus), forming nitrogen^{13} and a bundle of gamma rays,

$$C^{12} + H^{1} \rightarrow N^{13} + \gamma$$

(2) The resulting nitrogen^{13} emits a positron ($_1e^{\circ}$) and a neutrino (ν), yielding carbon^{13},

$$N^{13} \rightarrow C^{13} + {}_1e^{\circ} + \nu$$

(3) The carbon^{13} nucleus collides with another proton, forming nitrogen^{14} and releasing additional gamma energy,

$$C^{13} + H^{1} \rightarrow N^{14} + \gamma$$

(4) Nitrogen^{14} combines with still another proton, forming oxygen^{15},

$$N^{14} + H^{1} \rightarrow O^{15} + \gamma$$

(5) Oxygen^{15} breaks down into nitrogen^{15} by emitting a positron and a bundle of gamma rays,

$$O^{15} \rightarrow N^{15} + {}_{1}e^{0} + \gamma$$

(6) Finally, nitrogen^{15} combines with an extra proton to form carbon^{12} (regenerated at the end of the process), and helium,

$$N^{15} + H^{1} \rightarrow C^{12} + He^{4}$$

Thus, the over-all effect is the conversion of four protons (hydrogen nuclei) into helium, with a release of a tremendous quantity of energy. Carbon^{12} is recovered and may thus be regarded as a catalyst in the reaction.

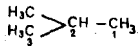
CARBON SCHEME SHOWING TYPES OF CARBON ARRANGEMENTS.

A. Carbon Chain Compounds.

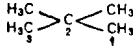
(1) Straight chain

$H_3C_3 - CH_2_2 - CH_3_1$ Propane (C_3H_8)

(2) Forked or branched chain



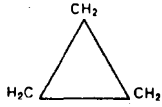
Trimethylmethane (C_4H_{10})
(2-Methylpropane)



Tetramethylmethane (C_4H_{10})
(2,2-Dimethylpropane)

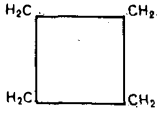
B. Carbon Ring Compounds Carbocyclic

(1) Three - carbon ring



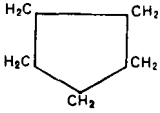
Cyclopropane (C_3H_6)

(2) Four - carbon ring



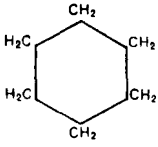
Cyclobutane (C_4H_8)

(3) Five - carbon ring

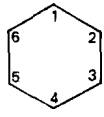


Cyclopentane (C_5H_{10})

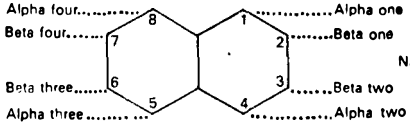
(4) Six - carbon ring



Cyclohexane (C_6H_{12})

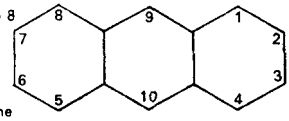


Benzene (C_6H_6)

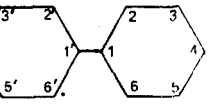


Naphthalene ($C_{10}H_8$)

Positions 1 to 8 are named alpha & beta as for naphthalene;
9, gamma one
10, gamma two



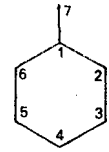
Anthracene ($C_{14}H_{10}$)



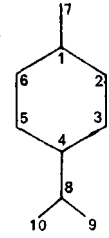
Diphenyl ($C_{12}H_{10}$)

C. Combinations of Carbon Chain and Carbon Ring

(1) Six-carbon plug

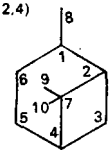


Carbon skeleton of toluene (C_7H_8 or $C_6H_5 \cdot CH_3$)



Carbon skeleton of limonene ($C_{10}H_{16}$), a terpene hydrocarbon

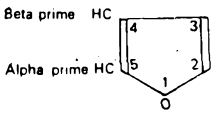
(2) Bridged ring (3 bridges from No. 2 to No. 4 (1) via No. 3. (2) via No. 7. (3) via No. 1. 6. 5. Therefore, "bicyclo [3.1.1] heptane") Numbers inside the square brackets denoting the number of carbons in each bridge-not counting the piers (No. 2,4)



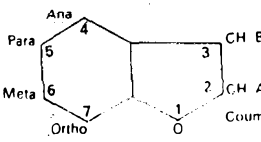
Carbon skeleton of pinene ($C_{10}H_{16}$), a terpene hydrocarbon

D. Heterocyclic Compounds

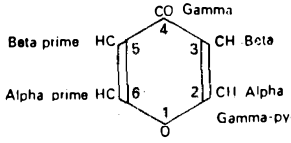
(1) Oxygen-carbon ring



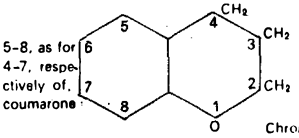
Furane (C_4H_4O)



Coumarone (C_8H_6O)

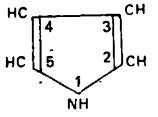


Gamma-pyrone ($C_5H_4O_2$)

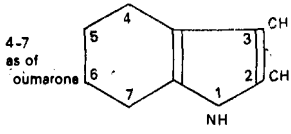


Chromane ($C_9H_{10}O$)

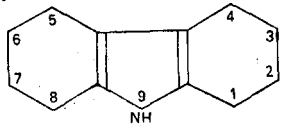
(2) Nitrogen-carbon ring



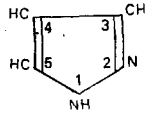
Pyrrole (C_4H_5N)



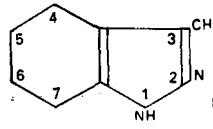
Indole (C_8H_7N)



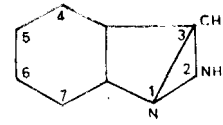
Carbazole ($C_{12}H_9N$)



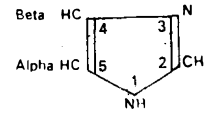
Pyrazole ($C_3H_4N_2$)



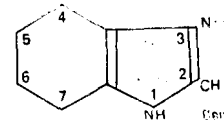
Isoindazole ($C_7H_6N_2$)



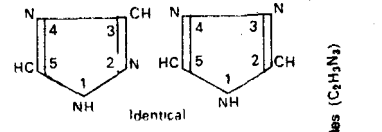
Indazole ($C_7H_6N_2$)

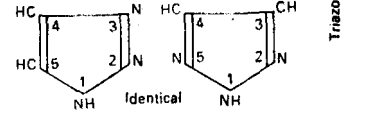


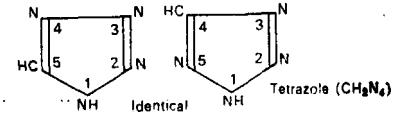
Iminazole ($C_3H_4N_2$)



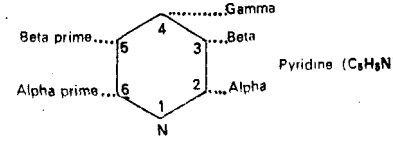
Benziminazole ($C_7H_6N_2$)



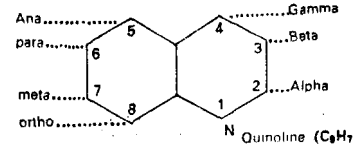




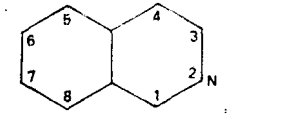
Tetrazole (CH_2N_4)



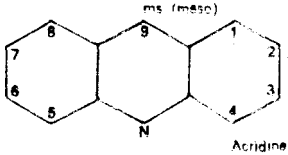
Pyridine (C_5H_5N)



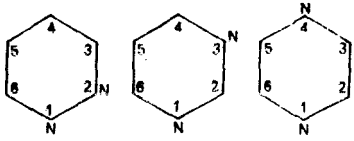
Quinoline (C_9H_7N)



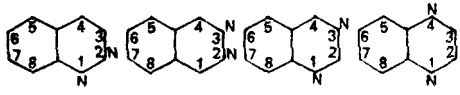
Isoquinoline (C_9H_7N)



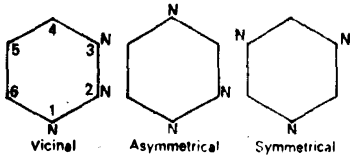
Acridine ($C_{13}H_9N$)



Three diazines ($C_4H_4N_2$)
1. 1.2 (Pyridazine)
2. 1.3 (Pyrimidine)
3. 1.4 (Pyrazine)

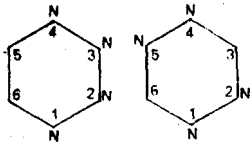


Four benzodiazines
1. 1.2 (cinnoline)
2. 2.3 (phthalazine)
3. 1.3 (quinazoline)
4. 1.4 (quinoxaline)



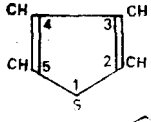
Vicinal Asymmetrical Symmetrical

Three triazines
1. 1.2.3
2. 1.2.4
3. 1.3.5 (cyanidine)



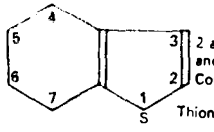
Two triazines
1. 1.2.3.4
2. 1.2.4.5

(3) Sulphur-carbon ring



2 to 5 alpha and beta, as of furane

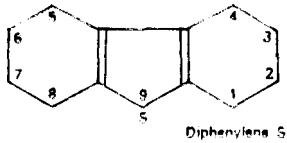
Thiophene (C_4H_4S)



4-7 as of Coumarone

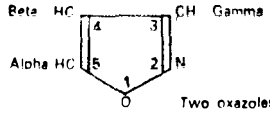
2 and 3, alpha and beta, as of Coumarone

Thionaphthene (C_8H_6S)

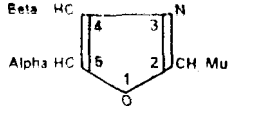


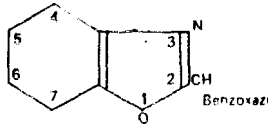
Diphenylene Sulphide ($C_{12}H_8S$)

(4) Oxygen - nitrogen - carbon ring

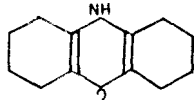


Two oxazoles (C_3H_3NO)
1. 1 - O - 2 - N
2. 1 - O - 3 - N



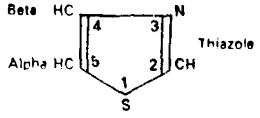


Benzoxazole (C_7H_5NO)

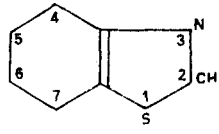


Phenoxazine ($C_{12}H_9NO$)

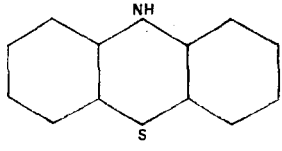
(5) Sulphur - nitrogen - carbon ring



Thiazole (C_3H_3NS)



Benzthiazole (C_7H_5NS)



Phenothiazine ($C_{12}H_9NS$)

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